MEMORANDUM REPORT M66-12-1

MATHEMATICAL SIMULATION OF HELICOPTER EMERGENCY EGRESS TRAJECTORIES

by

LEONARD A. DeSTEFANO

November 1965

AMCMS Code 5011.11.857

Distribution of this report is unlimited.

UNITED STATES ARMY
FRANKFORD ARSENAL
PHILADELPHIA, PA.

MEMORANDUM REPORT M66-12-1

MATHEMATICAL SIMULATION OF HELICOPTER EMERGENCY EGRESS TRAJECTORIES

by

LEONARD A. DeSTEFANO

AMCMS Code 5011.11.857

Distribution of this report is unlimited.

Propellant Actuated Devices Division
Components Engineering Directorate
FRANKFORD ARSENAL
Philadelphia, Pa. 19137

November 1965

ABSTRACT

The basic equations of motion for a point mass under the influence of gravity, aerodynamic drag, and rocket forces are used to simulate a three-dimensional, three-degree of freedom, helicopter emergency egress trajectory. The resulting equations of motion were solved by a fourth order Runge Kutta method, programmed in Fortran for the Univac Solid State 90 digital computer.

Included in this report is the computer program which was used to obtain a numerical solution to the equations of motion, the solution to three test cases, and a comparison with an experimental trajectory.

TABLE OF CONTENTS

List of Tables

List of Illustrations

List of Illustrations (Cont'd)

INTRODUCTION

Operational experience with Army helicopters reveals many instances where in-flight hazards to crew personnel may be effectively resolved, with a resultant increase in flight safety, through the use of an emergency escape system.

In this report, the basic equations of motion for a point mass under the influence of gravity, aerodynamic drag, and rocket forces are used to simulate a three-dimensional, three-degree of freedom, helicopter emergency egress trajectory. The resulting equations of motion were solved by a fourth order Runge Kutta method, programmed in Fortran for the Univac Solid State 90 digital computer. The computer program which was used to obtain a numerical solution to the equations of motion is presented in Appendix A.

The purpose of this report is to document the analytical capability necessary to evaluate the egress trajectories associated with such emergency escape systems.

ASSUMPTIONS

1. The seat-man combination is treated as a point mass.

2. Time, $t = 0$, begins at the end of the catapult stroke, at which time the catapult has imparted some initial velocity to the seat-man combination.

3. Aerodynamic drag is proportional to the n^{th} power of the velocity. In the test cases presented, n is 2.

4. Rocket thrust is constant in both magnitude and direction throughout the burn time.

5. The helicopter pitch angle is zero at the time of ejection.

6. Parachute forces are omitted.

DISCUSSION

The helicopter emergency egress trajectory analyzed in this report is accomplished initially by a catapult (which ejects the seat-man laterally) and, after a suitable delay, by a rocket (which raises the escapee to a height sufficient for safe recovery by parachute). The analysis begins at the end of catapult stroke ($t = 0$), at which time the seat-man has acquired an initial velocity due to both the catapult and the velocity of the supporting vehicle. The magnitude and direction of these velocities are inputs to the program.

The trajectory can be thought of in terms of the following three stages:

1. Initial "Free" Flight Stage - The motion of the seat-man, determined by the initial conditions, continues under the influences of only gravity and drag up to time t_1.

2. Rocket Stage - At time t_1, a rocket force (R) becomes effective. This force, constant in time and direction, terminates at time $t_1 + t_b$. The delay between ejection ($t = 0$) and rocket initiation (t_1) allows the seat-man sufficient time to clear the rotor blades before being propelled upward. The magnitude and direction of R, t_1, and t_b are all inputs to the program.

3. Final "Free" Flight Stage - At time $t_1 + t_b$, the seat-man continues its trajectory, influenced only by gravity and drag.

The trajectory is terminated automatically in either of two ways: (1) when ground impact is achieved, i.e., when the vertical coordinate, x_3, first becomes negative; or (2) when a terminal time read into the computer as input data is reached; whichever occurs first.

THE COORDINATE SYSTEM

A right-handed orthogonal coordinate system (Figure 1) is employed with the mutually orthognal axes being defined in the following manner.

The $+x_3$ axis is chosen to be in a direction antiparallel to that of the acceleration due to gravity. The roll axis of the helicopter was chosen as the x_1 axis, with the fore end of the helicopter defining the + direction. The x_2 axis is then so oriented as to complete the right-handed orthogonal system. The x_1, x_2, and x_3 cordinate axes are referred to as x, y, and z, respectively, in the computer input/output formats.

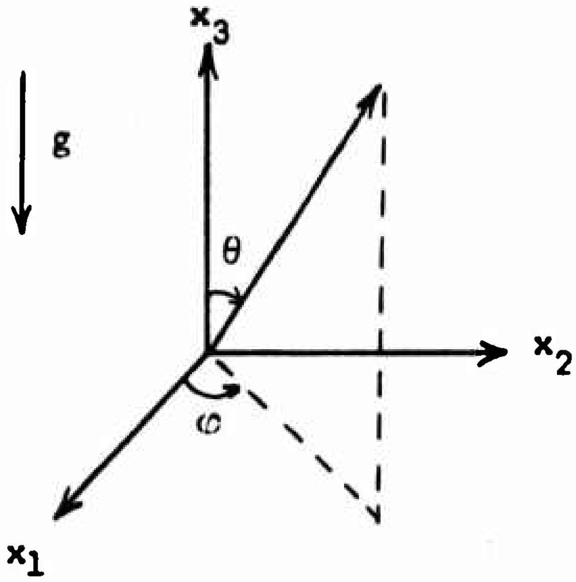

Figure 1. The Coordinate System

All directional inputs to the program are read into the computer in terms of the angles θ and φ (the colatitude and azimuth, respectively) referenced with respect to this space set of axes fixed at the instant of ejection.

EQUATIONS OF MOTION

Summing forces (see Appendix B for symbols used)

$$\sum_j F_i^{(j)} = m\ddot{x}_i \qquad (1)^*$$

where

$$F_i^{(1)} = \begin{cases} -mg & \text{for } i = 3 \\ 0 & \text{for } i = 1, 2 \end{cases} \qquad \text{(Gravity)}$$

$$F_i^{(2)} = -k\, v^n\, v_i/v = -k\, v^{n-1}\, v_i \qquad \text{(Drag)}$$

$$F_i^{(3)} = \begin{cases} R_i & \text{for } t_1 \le t \le t_1 + t_b \\ 0 & \text{otherwise} \end{cases} \qquad \text{(Rocket)}$$

and

$$\ddot{x}_i = \dot{v}_i \qquad (2)$$

$$v = (v_1^2 + v_2^2 + v_3^2)^{1/2} \qquad (3)$$

---

*Dots represent differentiation with respect to time.

Combining Equations 1, 2, and 3 for n = 2,

$$m\dot{v}_i = F_i^{(2)} - k\ v\ v_i + F_i^{(3)} \tag{4}$$

METHOD OF SOLUTION

Equation 4 represents the three simultaneous differential equations:

$$\dot{v}_1 = -\frac{k}{m}\ v\ v_1 + F_1^{(3)}$$

$$\dot{v}_2 = -\frac{k}{m}\ v\ v_2 + F_2^{(3)}$$

$$\dot{v}_3 = -g - \frac{k}{m}\ v\ v_3 + F_3^{(3)}$$

These three equations, when coupled with

$$\dot{x}_1 = v_1$$

$$\dot{x}_2 = v_2$$

$$\dot{x}_3 = v_3$$

result in six first order differential equations which are integrated numerically using a fourth order Runge Kutta method to obtain the velocities and coordinates as functions of time:

$$v_i = v_i(t)$$

$$x_i = x_i(t).$$

COMPUTER INPUT FORMAT

The data input format for the computer program is listed in Table I. The input data are read into the computer on a series of 18 cards, in the order shown. The first card titles each particular trajectory simulation. This information is punched into the first portion of the card, beginning in column 1. If a title is not desired, a blank card must be substituted. The next 17 cards contain

the necessary input data. Parameter titles are punched into columns 1 through 45. Columns 47 through 90 are reserved for the numerical values of the input, column 46 containing the input sign.

An example of a suggested format is shown in the initial portion of the computer printout (Figure 2) for Test No. 1. The Fortran symbols designating the various inputs to the computer program are also listed in Table I.

TABLE I. Input Data

Test No. _______

Fortran Symbols	Parameter	Unit
D(1)	Initial height	ft
D(2)	Vehicle velocity	ft/sec
D(3)	Catapult velocity	ft/sec
D(4)	Rocket thrust	lb
D(5)	Vehicle colatitude, θ	degree
D(6)	Vehicle azimuth, φ	degree
D(7)	Catapult colatitude, θ	degree
D(8)	Catapult azimuth, φ	degree
D(9)	Rocket colatitude, θ	degree
D(10)	Rocket azimuth, φ	degree
D(11)	Rocket initiation time	sec
D(12)	Rocket burn time	sec
D(13)	Ejected mass	slugs
D(14)	Drag coefficient	$lb(sec/ft)^n$
D(15)	Drag exponent	dimensionless
D(16)	Time increment	sec
D(17)	Terminal time	sec

Explanation of the input data follows.

D(1) - The initial height of the seat-man configuration.

D(2) - The magnitude of the helicopter velocity at t = 0.

D(3) - Magnitude of the velocity imparted to the seat-man by the catapult at t = 0.

D(4) - Rocket thrust.

D(5), D(6) - The direction of the vehicle velocity at t = 0 referenced with respect to the space set of axes.

D(7), D(8) - The direction of the catapult velocity referenced with respect to the space set of axes.

HELICOPTER EGRESS TRAJECTORY ANALYSIS

TEST NO. 1

INITIAL HEIGHT (FT)	5.00000
VEHICLE VELOCITY (FT/SEC)	0.00000
CATAPULT VELOCITY (FT/SEC)	60.00000
ROCKET THRUST (LBS)	3400.00000
VEHICLE COLATITUDE, THETA (DEG)	90.00000
VEHICLE AZIMUTH, PHI (DEG)	0.00000
CATAPULT COLATITUDE, THETA (DEG)	90.00000
CATAPULT AZIMUTH, PHI (DEG)	90.00000
ROCKET COLATITUDE, THETA (DEG)	36.25000
ROCKET AZIMUTH, PHI (DEG)	0.00000
ROCKET INITIATION TIME (SEC)	.30000
ROCKET BURN TIME (SEC)	.35000
EJECTED MASS (SLUGS)	9.32430
DRAG COEFFICIENT (LBS-(SEC/FT)**N)	.00600
DRAG EXPONENT (DIM)	2.00000
TIME INCREMENT (SEC)	.05000
TERMINAL TIME (SEC)	10.00000

T	X	Y	Z	VX	VY	VZ	AX	AY	AZ
0.00	0.00	0.00	5.00	.00	60.00	.00	-.00	-2.31	-32.17
.05	.00	2.99	4.95	.00	59.88	-1.60	-.00	-2.30	-32.11
.10	.00	5.98	4.83	.00	59.76	-3.20	-.00	-2.30	-32.05
.15	.00	8.97	4.63	.00	59.65	-4.81	-.00	-2.29	-31.98
.20	.00	11.95	4.35	.00	59.53	-6.40	-.00	-2.29	-31.92
.25	.00	14.92	3.99	.00	59.42	-8.00	-.00	-2.29	-31.86
.30	.00	17.89	3.55	1.79	59.31	-7.14	215.54	-2.28	262.16
.35	.35	20.85	3.52	12.56	59.19	5.95	215.11	-2.31	261.65
.40	1.25	23.81	4.15	23.30	59.07	19.01	214.61	-2.52	261.07
.45	2.69	26.76	5.42	34.02	58.94	32.05	213.96	-2.85	260.33
.50	4.65	29.70	7.35	44.70	58.78	45.05	213.12	-3.27	259.38
.55	7.15	32.64	9.93	55.33	58.61	57.99	212.07	-3.74	258.18
.60	10.19	35.57	13.15	65.90	58.41	70.86	210.81	-4.24	256.73
.65	13.74	38.48	17.01	76.41	58.18	83.65	209.34	-4.76	255.03
.70	17.65	41.38	21.27	77.88	57.94	84.14	-6.43	-4.79	-39.13
.75	21.53	44.28	25.43	77.56	57.70	82.19	-6.33	-4.71	-38.88
.80	25.40	47.16	29.49	77.24	57.47	80.25	-6.23	-4.63	-38.64
.85	29.26	50.02	33.46	76.94	57.24	78.33	-6.13	-4.56	-38.41

Figure 2. Initial Portion of Computer Printout for Test 1

D(9) } Direction of rocket thrust referenced with respect to the
D(10) } space set of axes.

D(11) - Rocket initiation time.

D(12) - Rocket burn time.

D(13) - Mass of seat-man combination.

D(14) - Drag coefficient equal to $\rho A C_D/2$, where ρ is the air density ($slugs/ft^3$); A, the seat area (ft^2); and C_D, an aerodynamic coefficient (dimensionless) taken equal to 1.

D(15) - Velocity exponent in the velocity dependent drag force.

D(16) - Compute and print interval.

D(17) - Time at which the program terminates if ground impact has not occurred.

RESULTS OF COMPUTER ANALYSIS

Approximately twelve computer tests were run; the results of three (tests 1, 5, and 6) are given in Figures 3, 4, and 5. The input for these tests is presented in Table II.

The computer simulation was compared to data from experimental trajectories.* Test 1 is such a comparison. The input values were chosen to correspond to those of the actual ejection. Figure 2 is the initial portion of the computer printout for this test. Coordinates (x, y, z) are expressed in feet; velocities (v_x, v_y, v_z), in ft/sec; and accelerations (A_x, A_y, A_z), in ft/sec^2. The trajectory is referenced with respect to the point of ejection. Comparison between experimental and computer results is presented in Table III.

Tests 5 and 6 were run using the same aerodynamic and rocket data, but with different initial heights and vehicle velocities.

A suitable method of graphically portraying the three-dimensional trajectory is shown in Figures 3, 4, and 5. Two graphs (A and B) determine each trajectory. The first (A) is a graph of altitude (z) vs time (t), with the various events indicated along the time axis. The second (B) is a graph of the horizontal components x vs y, again with the various events indicated. The two graphs are sufficient to determine the complete space-time trajectory.

---

* M. Weinstock, "Emergency Escape Systems for Army Helicopters," Aerospace Medicine, Vol 36, No. 3, March 1965.

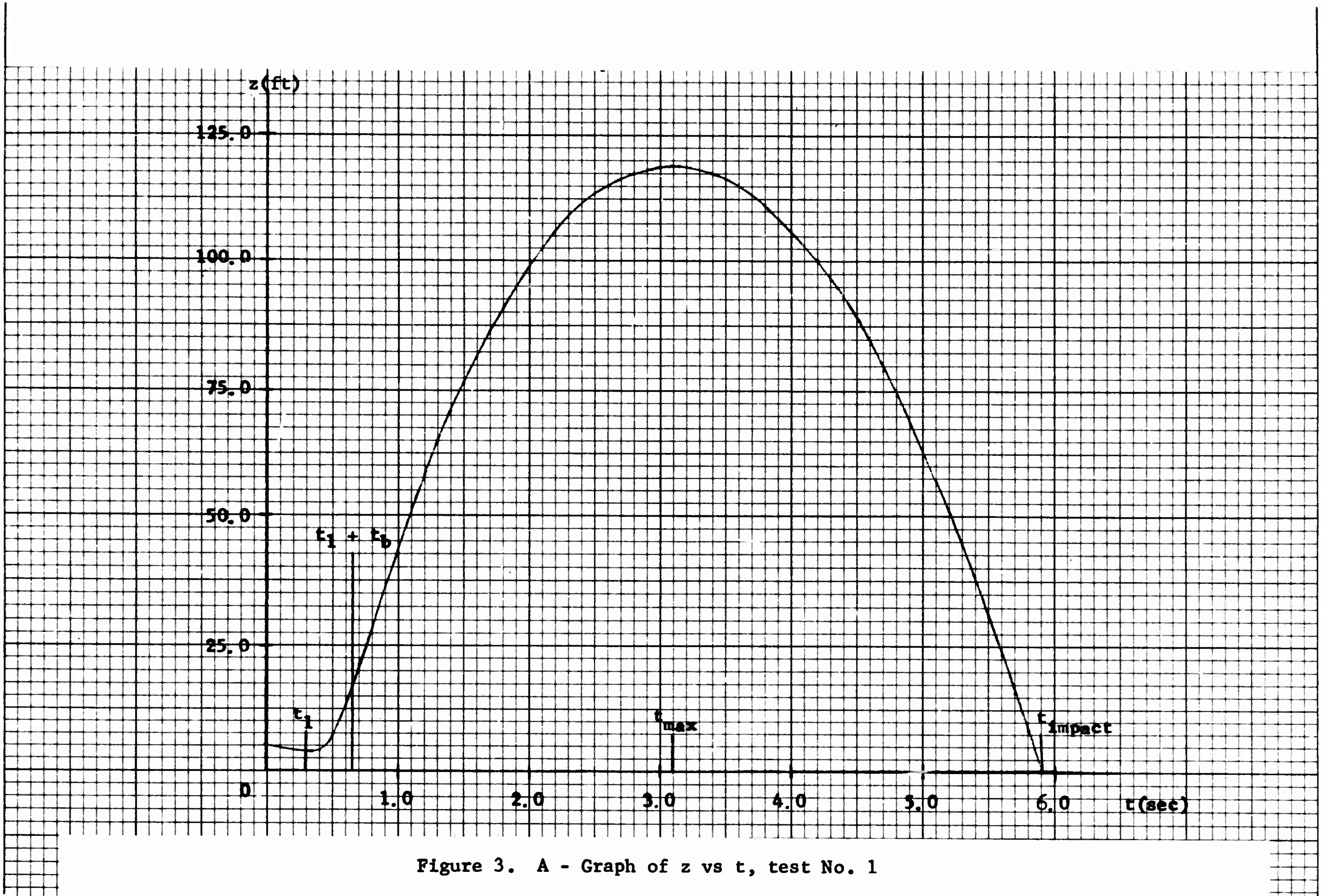

Figure 3. A - Graph of z vs t, test No. 1

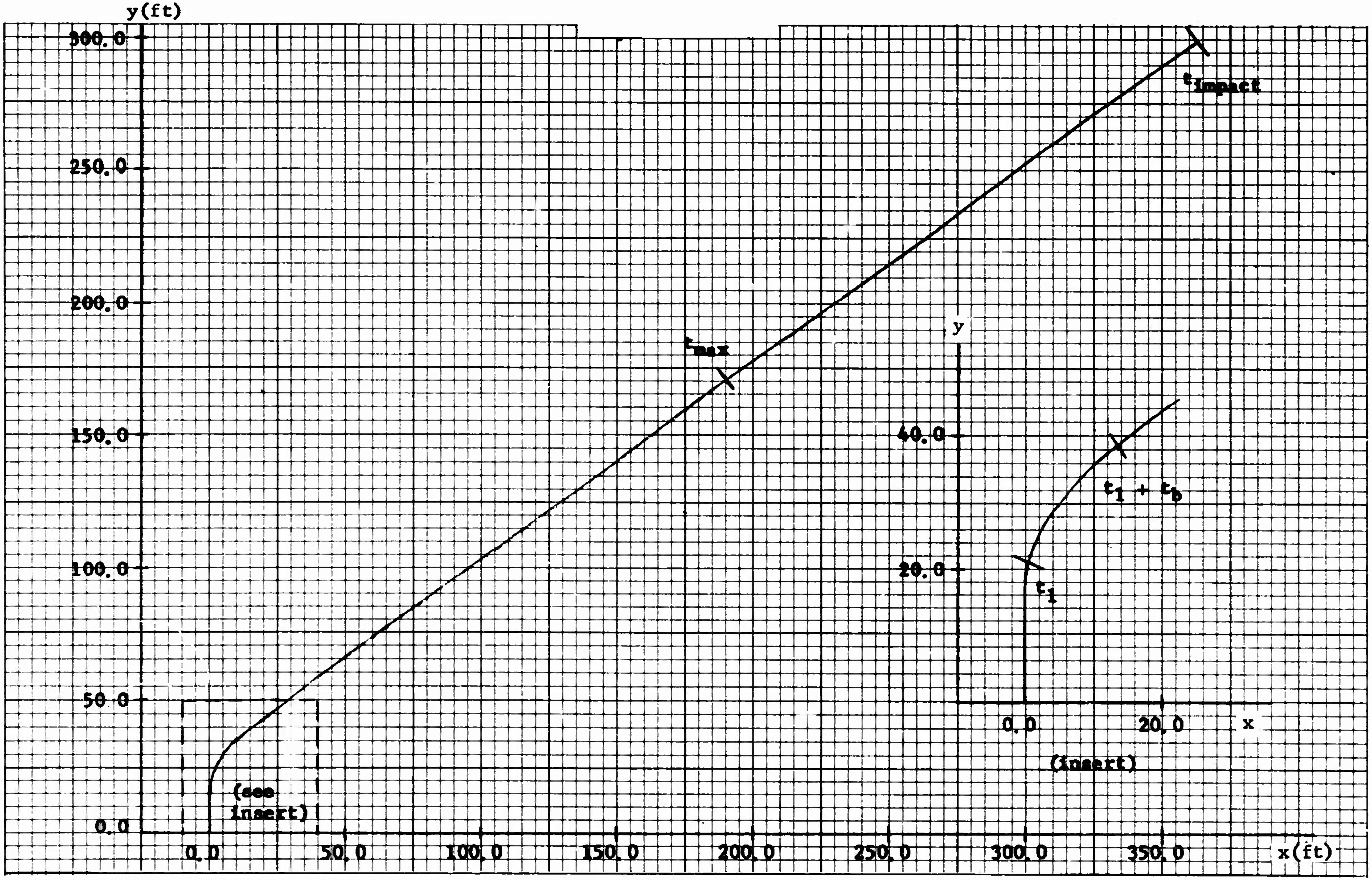

Figure 3. B - Graph of x vs y, test No. 1

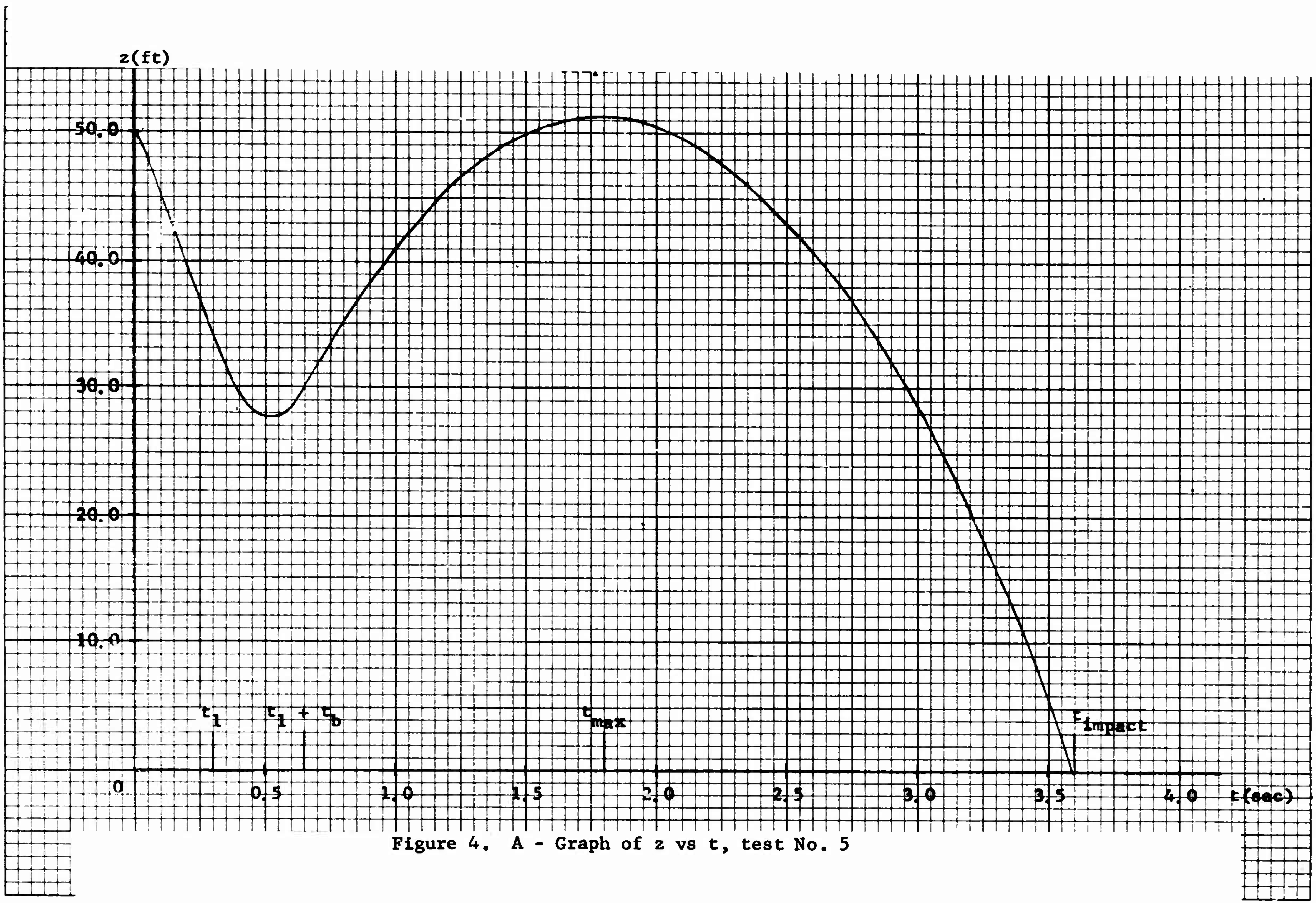

Figure 4. A - Graph of z vs t, test No. 5

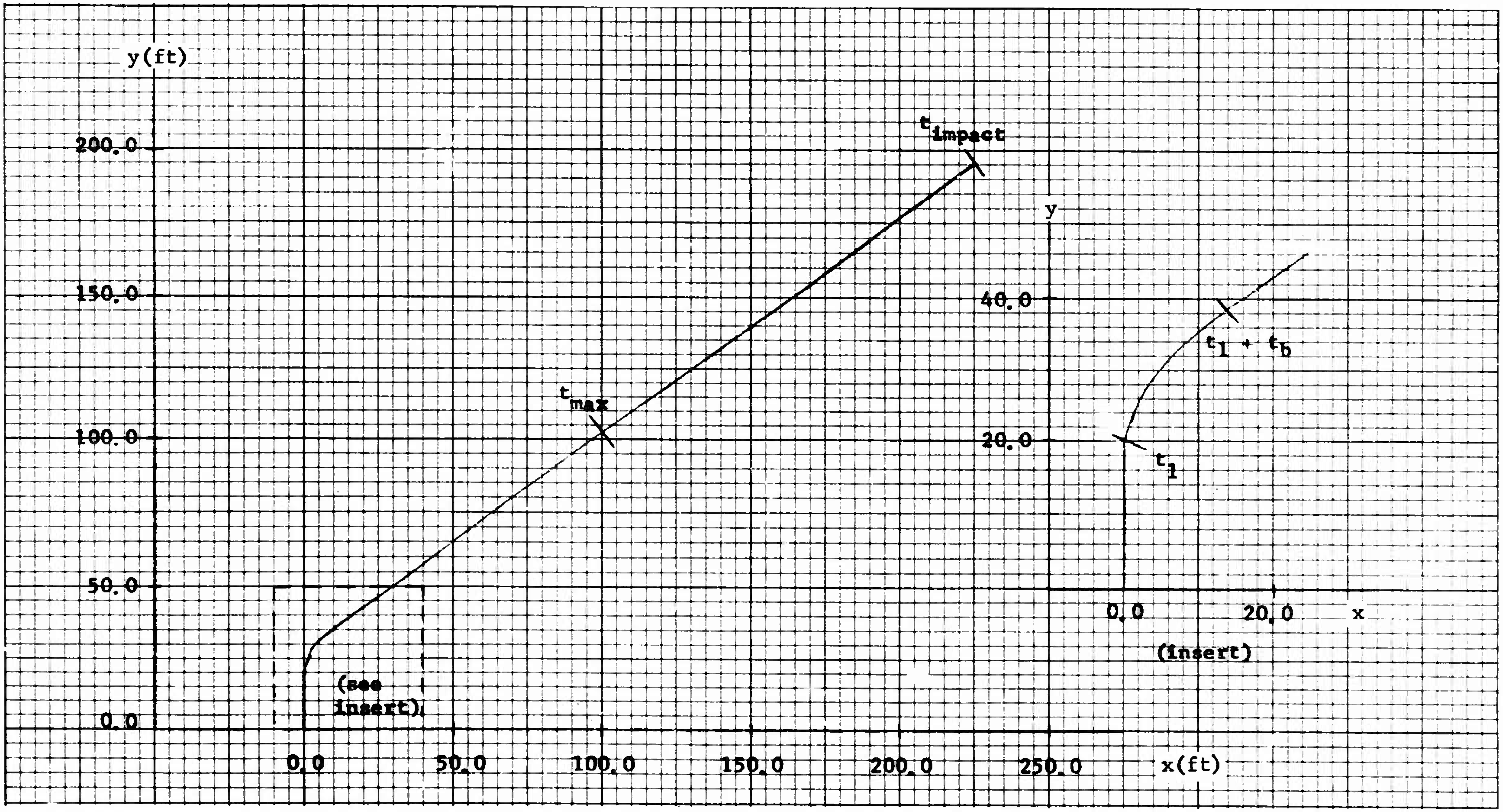

Figure 4. B - Graph of x vs y, test No. 5

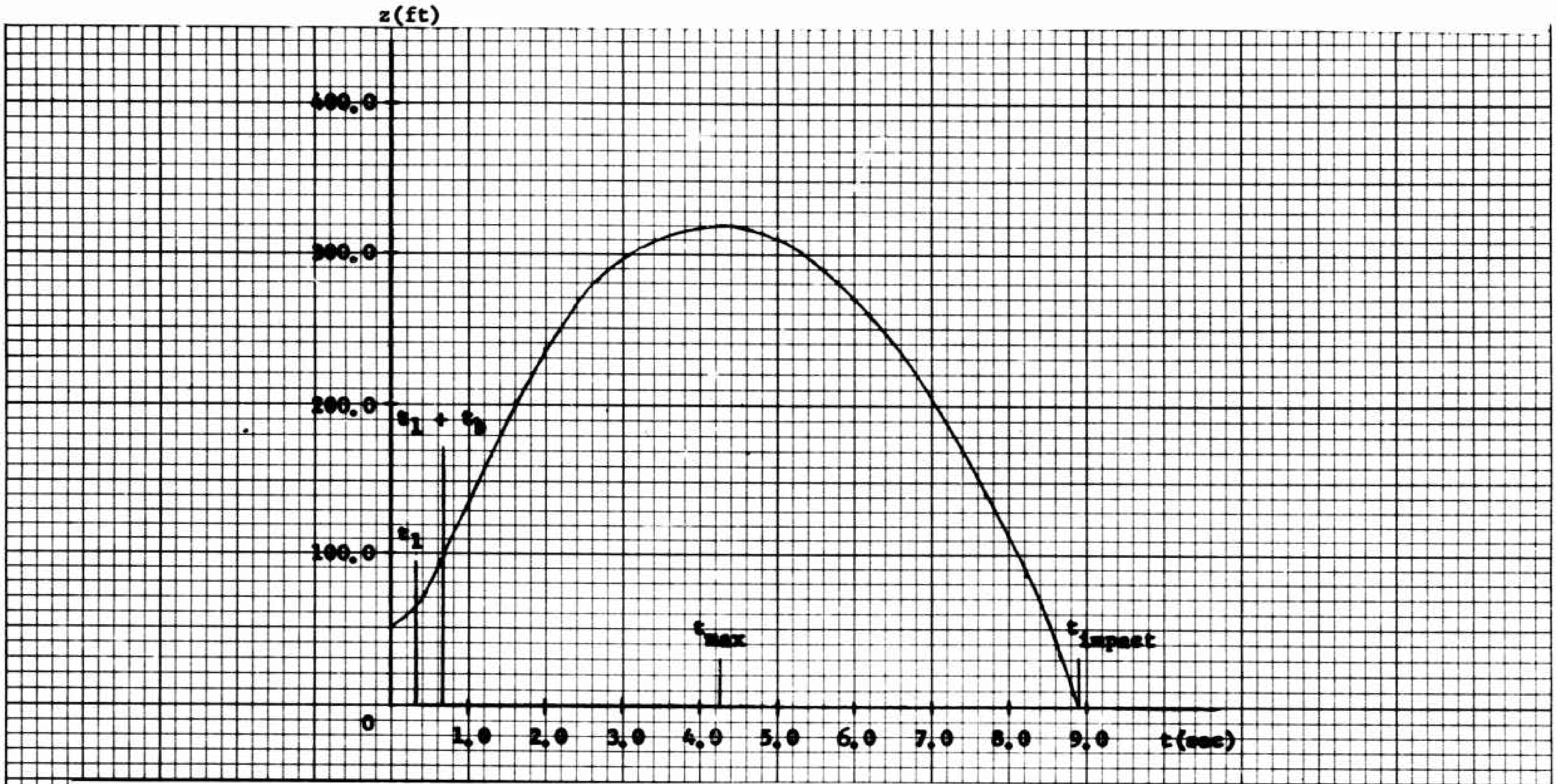

Figure 5. A - Graph of z vs t, test No. 6

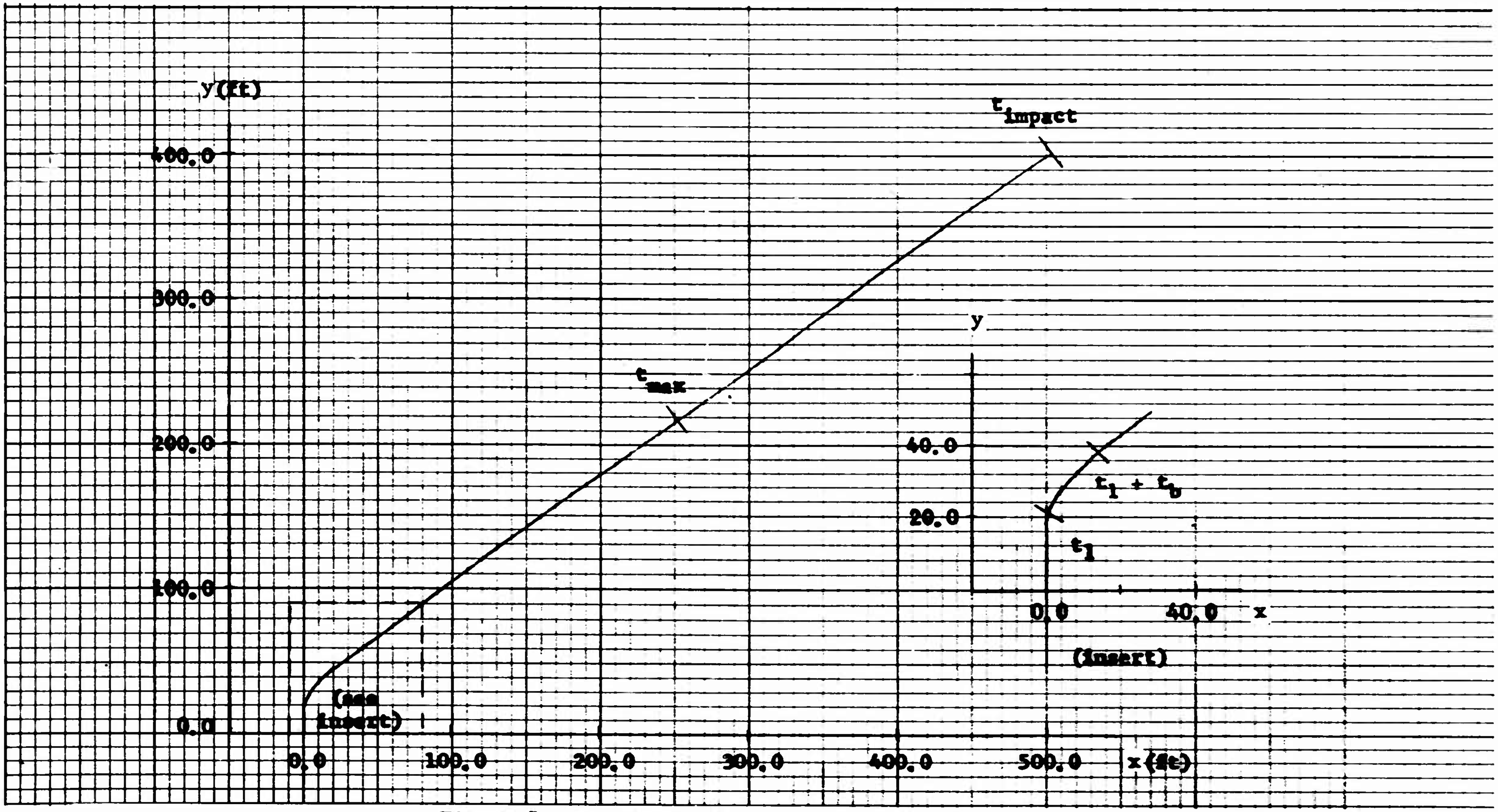

Figure 5. B - Graph of x vs y, test No. 6

TABLE II. Input for Tests 1, 5, and 6

Parameter		Test 1	Test 5	Test 6
Initial height	(ft)	5.0	50.0	50.0
Vehicle velocity	(ft/sec)	0.0	50.0	50.0
Catapult velocity	(ft/sec)	60.0	60.0	60.0
Rocket thrust	(lb)	3400.0	3400.0	3400.0
Vehicle colatitude	(degree)	90.0	180.0	0.0
Vehicle azimuth	(degree)	0.0	0.0	0.0
Catapult colatitude	(degree)	90.0	90.0	90.0
Catapult azimuth	(degree)	90.0	90.0	90.0
Rocket colatitude	(degree)	36.25	36.25	36.25
Rocket azimuth	(degree)	0.0	0.0	0.0
Rocket initiation time	(sec)	0.3	0.3	0.3
Rocket burn time	(sec)	0.35	0.35	0.35
Ejected mass	(slugs)	9.3243	9.3243	9.3243
Drag coefficient	$(\text{lb/sec/ft})^n$	0.006	0.006	0.006
Drag exponent	(dimensionless)	2.0	2.0	2.0
Time increment	(sec)	0.05	0.05	0.05
Terminal time	(sec)	10.0	10.0	10.0

TABLE III. Comparison between Experimental and Computed Trajectory

	Max Height (ft)	Max v_x (ft/sec)	Max v_y (ft/sec)	Max v_z (ft/sec)
Experimental	120 to 130	72	60	100
Computed	119	78	60	84

No horizontal displacement data are available for comparison, and no meaningful comparison between acceleration levels is possible because of the following assumptions made in the analysis:

1. The catapult which, in the experimental trajectory, caused the maximum acceleration is assumed to impart an initial velocity only;

2. Rocket thrust is assumed constant over the burn time.

CONCLUSIONS

Comparison with experimental data indicates that the analysis presented in this report adequately simulates experimental helicopter egress trajectories.

RECOMMENDATIONS

It is recommended that

1. The analytical capability provided here be utilized in future analyses of helicopter egress trajectories and any other trajectory simulation fulfilling the stated assumptions.

2. This analysis be extended to include the effect of parachute forces and rotation in the pitch plane.

APPENDIX A

THE COMPUTER PROGRAM

```
C     HELICOPTER EGRESS TRAJECTORY ANALYSIS
      DIMENSION A(10),B(10),C(10),D(25),F(10),HED(9),S(10),U(10)
      PRINT 402,
      PRINT 401,
      READ 202,HED
      PRINT 203,HED
      PRINT 401,
      DO 300 I#1,17
      READ 200,HED,D(I)
  300 PRINT 204,HED,D(I)
      PRINT 401,
      PRINT 400,
C     CONSTANTS
      T2#D(11)+D(12)
      D(9)#D(9)-90.
      D(10)#D(10)-90.
      DO 60 I#5,10
   60 D(I)#.017453*D(I)
      DO 70 I#5,8
   70 A(I)#SIN(D(I))
      DO 80 I#5,8
   80 B(I)#COS(D(I))
      C1#SIN(D(7)+D(9))
      C2#COS(D(7)+D(9))
      C3#SIN(D(8)+D(10))
      C4#COS(D(8)+D(10))
      C5#D(2)*A(5)*B(6)
      C6#D(2)*A(5)*A(6)
      C7#D(2)*B(5)
      C8#D(3)*A(7)*B(8)
      C9#D(3)*A(7)*A(8)
      C10#D(3)*B(7)
      C11#D(4)*C1*C4/D(13)
      C12#D(4)*C1*C3/D(13)
      C13#D(4)*C2/D(13)
      C14#-D(14)/D(13)
      C15#2.*D(16)
      C16#.5*D(16)
C     INITIAL CONDITIONS
      J#1
      T#0.
      XD#C5+C8
      YD#C6+C9
      ZD#C7+C10
      X#0.
      Y#0.
      Z#D(1)
      F(1)#XD
      F(2)#YD
      F(3)#ZD
      F(4)#X
      F(5)#Y
      F(6)#Z
```

```
C     ENTER EVALUATION ROUTINE
  100 XD#F(1)
      YD#F(2)
      ZD#F(3)
      X#F(4)
      Y#F(5)
      Z#F(6)
      V#SQRT(XD*XD+YD*YD+ZD*ZD)
      IF(T-D(11))2,1,1
    1 IF(T-T2)3,3,2
    2 RX#0.
      RY#0.
      RZ#0.
      GO TO 4
    3 RX#C11
      RY#C12
      RZ#C13
    4 VC14#C14*V**(D(15)-1.)
      S(1)#VC14*XD+RX
      S(2)#VC14*YD+RY
      S(3)#VC14*ZD+RZ-32.174
      S(4)#XD
      S(5)#YD
      S(6)#ZD
      F(1)#S(4)
      F(2)#S(5)
      F(3)#S(6)
      F(4)#X
      F(5)#Y
      F(6)#Z
      IF(T)6,5,6
    5 PRINT 201,T,F(4),F(5),F(6),F(1),F(2),F(3),S(1),S(2),S(3)
C     EXIT EVALUATION ROUTINE
    6 GO TO (10,20,30,40,50),J
C     ENTER RUNGE KUTTA ROUTINE
   10 DO 11 I#1,6
      U(I)#F(I)
      C(I)#D(16)*S(I)
   11 F(I)#U(I)+.5*C(I)
      T#T+C16
      J#2
      GO TO 100
   20 DO 21 I#1,6
      C(I)#C(I)+C15*S(I)
   21 F(I)#U(I)+C16*S(I)
      J#3
      GO TO 100
   30 DO 31 I#1,6
      C(I)#C(I)+C15*S(I)
   31 F(I)#U(I)+D(16)*S(I)
      T#T+C16
      J#4
      GO TO 100
```

```
 40 DO 41 I#1,6
 41 F(I)#U(I)+(C(I)+D(16)*S(I))/6.
    J#5
    GO TO 100
C      EXIT RUNGE KUTTA ROUTINE
 50 PRINT 201,T,F(4),F(5),F(6),F(1),F(2),F(3),S(1),S(2),S(3)
    J#1
    IF(Z)102,102,101
101 IF(T-D(17))100,102,102
102 STOP
200 FORMAT(9A5,                                        F16.5)
201 FORMAT(10F13.2)
202 FORMAT(9A5)
203 FORMAT(59X,9A5)
204 FORMAT(34X,9A5,                                        F16.5)
400 FORMAT(10X,1HT,12X,1HX,12X,1HY,12X,1HZ,12X,2HVX,11X,2HVY,11X,2HVZ,
   111X,2HAX,11X,2HAY,10X,2HAZ)
401 FORMAT(2/)
402 FORMAT(46X,37HHELICOPTER EGRESS TRAJECTORY ANALYSIS)
    END
```

APPENDIX B

SYMBOLS USED IN DERIVATION OF EQUATIONS OF MOTION

Symbol	Definition	Unit
F	Force	lb
g	Acceleration due to gravity	ft/sec^2
i	Subscript having values 1, 2, 3, corresponding to the three mutually perpendicular coordinate directions	dimensionless
j	Superscript having values 1, 2, 3, referring to the various force contributions	dimensionless
k	Drag coefficient	$lb(sec/ft)^n$
m	Mass of seat-man	slugs
n	Drag exponent	dimensionless
R	Rocket thrust	lb
t	Time	sec
t_1	Rocket initiation time	sec
t_b	Rocket burn time	sec
v	Velocity	ft/sec
x	Displacement	ft

UNCLASSIFIED

Security Classification

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY *(Corporate author)* FRANKFORD ARSENAL, Philadelphia, Pa. 19137 ATTN: SMUFA L3100	2a. REPORT SECURITY CLASSIFICATION Unclassified
	2b GROUP NA

3. REPORT TITLE

MATHEMATICAL SIMULATION OF HELICOPTER EMERGENCY EGRESS TRAJECTORIES

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*

Technical research report

5. AUTHOR(S) *(Last name, first name, initial)*

DeSTEFANO, Leonard A.

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
November 1965	23	One

8a. CONTRACT OR GRANT NO. AMCMS Code 5011.11.857	9a. ORIGINATOR'S REPORT NUMBER(S) M66-12-1
b. PROJECT NO.	
c.	9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)* U.S. Army Munitions Command
d.	

10. AVAILABILITY/LIMITATION NOTICES

Distribution of this report is unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY

13. ABSTRACT

The basic equations of motion for a point mass under the influences of gravity, aerodynamic drag, and rocket forces are used to simulate a three-dimensional, three-degree of freedom, helicopter emergency egress trajectory. The resulting equations of motion were solved by a fourth order Runge Kutta method, programmed in Fortran for the Univac Solid State 90 digital computer.

Included in this report is the computer program which was used to obtain a numerical solution to the equations of motion, the solution to three test cases, and a comparison with an experimental trajectory.

DD FORM 1 JAN 64 1473

UNCLASSIFIED

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Helicopter Egress Trajectories Egress Trajectory Analysis Computer Programming Propellant Actuated Devices Escape Systems						

INSTRUCTIONS

1. ORIGINATING ACTIVITY: Enter the name and address of the contractor, subcontractor, grantee, Department of Defense activity or other organization *(corporate author)* issuing the report.

2*a*. REPORT SECURITY CLASSIFICATION: Enter the overall security classification of the report. Indicate whether "Restricted Data" is included. Marking is to be in accordance with appropriate security regulations.

2*b*. GROUP: Automatic downgrading is specified in DoD Directive 5200.10 and Armed Forces Industrial Manual. Enter the group number. Also, when applicable, show that optional markings have been used for Group 3 and Group 4 as authorized.

3. REPORT TITLE: Enter the complete report title in all capital letters. Titles in all cases should be unclassified. If a meaningful title cannot be selected without classification, show title classification in all capitals in parenthesis immediately following the title.

4. DESCRIPTIVE NOTES: If appropriate, enter the type of report, e.g., interim, progress, summary, annual, or final. Give the inclusive dates when a specific reporting period is covered.

5. AUTHOR(S): Enter the name(s) of author(s) as shown on or in the report. Enter last name, first name, middle initial. If military, show rank and branch of service. The name of the principal author is an absolute minimum requirement.

6. REPORT DATE: Enter the date of the report as day, month, year; or month, year. If more than one date appears on the report, use date of publication.

7*a*. TOTAL NUMBER OF PAGES: The total page count should follow normal pagination procedures, i.e., enter the number of pages containing information.

7*b*. NUMBER OF REFERENCES: Enter the total number of references cited in the report.

8*a*. CONTRACT OR GRANT NUMBER: If appropriate, enter the applicable number of the contract or grant under which the report was written.

8*b*, 8*c*, & 8*d*. PROJECT NUMBER: Enter the appropriate military department identification, such as project number, subproject number, system numbers, task number, etc.

9*a*. ORIGINATOR'S REPORT NUMBER(S): Enter the official report number by which the document will be identified and controlled by the originating activity. This number must be unique to this report.

9*b*. OTHER REPORT NUMBER(S): If the report has been assigned any other report numbers *(either by the originator or by the sponsor)*, also enter this number(s).

10. AVAILABILITY/LIMITATION NOTICES: Enter any limitations on further dissemination of the report, other than those imposed by security classification, using standard statements such as:

(1) "Qualified requesters may obtain copies of this report from DDC."

(2) "Foreign announcement and dissemination of this report by DDC is not authorized."

(3) "U. S. Government agencies may obtain copies of this report directly from DDC. Other qualified DDC users shall request through ________________."

(4) "U. S. military agencies may obtain copies of this report directly from DDC. Other qualified users shall request through ________________."

(5) "All distribution of this report is controlled. Qualified DDC users shall request through ________________."

If the report has been furnished to the Office of Technical Services, Department of Commerce, for sale to the public, indicate this fact and enter the price, if known.

11. SUPPLEMENTARY NOTES: Use for additional explanatory notes.

12. SPONSORING MILITARY ACTIVITY: Enter the name of the departmental project office or laboratory sponsoring *(paying for)* the research and development. Include address.

13. ABSTRACT: Enter an abstract giving a brief and factual summary of the document indicative of the report, even though it may also appear elsewhere in the body of the technical report. If additional space is required, a continuation sheet shall be attached.

It is highly desirable that the abstract of classified reports be unclassified. Each paragraph of the abstract shall end with an indication of the military security classification of the information in the paragraph, represented as *(TS)*, *(S)*, *(C)*, or *(U)*.

There is no limitation on the length of the abstract. However, the suggested length is from 150 to 225 words.

14. KEY WORDS: Key words are technically meaningful terms or short phrases that characterize a report and may be used as index entries for cataloging the report. Key words must be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location, may be used as key words but will be followed by an indication of technical context. The assignment of links, rules, and weights is optional.